Question and Answer Summary: Phytoremediation

Peconic River Remedial Alternatives Workshop

Applied Phytogenetics, Inc. (Dr. Meagher)

Question (Mary Logan): Have you had any resistance to introducing genetically engineered plants into the environment?

Reply: I get a lot of discussion about it. You can imagine I made a presentation; Gene Ottum is quite a good ecologist, is the one that turned both our papers into PNES and he is very supportive, not because he is not concerned about it but because the way he described it to his ecology students who were tearing me apart at the seminar was that when you have these big system problems and you fail with every other solution, you need to start looking for other reduction and solutions which is the way they view our genetic engineering approach and I think we have a lot we can do. We can use sterile rice varieties. We're concentrating on trees because we believe we can control the release of any kind of seeds from those plants more easily. We really have a number of strategies for trying to control genetic and modified plants. I'm also one of those who believe that the Europeans are "knee deep" in their pesticide pollution. American farmers are getting a great solution with that with genetically engineered plants, and that I think Europe has this kind of upside down right now in terms of using GMO's to try and help clean up the environment. I think we have hundreds of opportunities here and yes, there will be resistance and some fears about it, but I think if we talk about it and tell people what we can do to control it, we'll conquer those fears.

Question: (inaudible)

Reply: I don't know the answer about competitive exclusion. I think the reason if you actually just look at reactivity, ionic mercury is more reactive than methyl mercury. But if you look at what happens when the two compounds go through the gut of each organism in that trophic level, the ionic mercury is so reactive that it reacts with everything in the gut and stays in the gut and is passed out. The methyl mercury is 50 fold portioned; 50 fold times more efficiently portioned so that you'll get about 98% of it taken up through the gut wall and I think the reason that it's a neurotoxin is that the methyl group makes it very membrane soluble where the nervous system is full of membranes and it goes right there.

Question (Marsden Chen): What thicknesses of sediment of soil are you cleaning up with the plants?

Reply: It depends a lot on the particular plants you use. It depends on the soil and what your target goals are. You can trench the site and get roots down very deeply. You hear about people trenching down 10 to 15 feet. You get the roots to go that far. In most cases we're trying to hope to go 18 to 24 inches. If you feed the plants the right things you can get that. We have places in Georgia where the soil – you hit clay at 8 inches or something, but the site that I just showed you the picture of – we will certainly get down to two feet there without too much trouble with most of the species we are using.

Question (Marsden Chen): (Theoretical question) You have now cleaned up the first 8 to 24 inches, what about the stuff beneath that?

Reply: Well, I think you have to decide really what your goals are. In this case we believe that most of the contaminants at that site I showed you (this is the one with the benzene, methylene chloride and chloroform) – we believe that most of the solvent is moving to the surface layers. It's seeping out just above the area that we're planting. We think most of it moves to the surface. Now there's certainly some deep-water contamination and we're not sure what's going to happen. In some cases that moves so slowly we think that by taking care of 99% of the stuff in the surface water we'll get down to the target levels at the effluent (exit point from the site). But we're going to find that out as we monitor the site over the next six to eight months. So – the other thing you can consider: many of the sites (the ones we're working on) have a pump system in place already. We would like to pump that liquid up and put it under just below the root systems of our plants. Try to get it where the plants can get at it. So you don't have to spray to get it to the plants. We can probably find some safe way of bringing it up from underground and using the plants to degrade it.

CH2M Hill, Inc.

Question and answer session was bypassed to keep the session on time.

Edenspace Systems Corporation

Question: Your last two frames raised some very interesting questions, and obviously time is running a bit late here. By the time you can get your first plant into… for the phytoextraction, can you give me a ballpark time frame when you could get to that point?

Reply: From now until we have the data to put the first plant in the system?

Question: **Yes.**

Reply: I can give you an estimate, but I would think that you're going to want to do some… there's going to be some initial laboratory studies that are probably going to be on the order of six months, and then you're probably going to want to do a pilot scale in the field where you can start putting plants in. The problem is you never know what you're going to find when you start

doing these studies and looking for something that's going to remove silver, copper and mercury all at the same time from the sediments. That's going to be a challenge. You would like to think you could do that in a year. It may take longer than that, but I think that would be the time frame that you would have to look at and say, "Well, we're either going to have a solution by then or we're not." We'll have a better idea of where we're going by then.

Question: Have you looked at ways for using evapotranspiration to increase the migration gradient – basically to use the flow of water – flux through plants as a means for removing metals to the plants as opposed to having to disturb the site and causing more damage maybe.

Reply: I think that using transpiration… you're referring to… using transpiration to move water through the plant tissue, I think – that's primarily the mechanism.

Question: (inaudible)

Reply: I think using the existing vegetation is probably a very important part of the process, if that's what you're alluding to, rather than going in and removing what's there. Using what's there…there may be a possibility for that, but right now we don't know how that would work.

Phytokinetics, Inc. (Art Ferro)

Question: I was wondering why you chose the 8 week cycle for flooding and anaerobic (4 weeks) as opposed to longer and shorter… I'm thinking of our title cycle here. I know you had nothing to do what we're doing here but would there be more coupling if it were a shorter cycle possibly?

Reply: Possibly. Yeah. We picked that because we had a very limited analytical budget and we wanted….. so we didn't want to go through many sampling events. It was sort of a compromise. Our reading of the literature indicated that these compounds were extremely recalcitrant and so we wanted to give it, you know, that amount of time under each redox state.

Question: Was there ever an actual experiment in the field?

Reply: Unfortunately not.

Question: I was wondering the reason for this?

Reply: Our client kind of … there was a change in the bureaucracy of this company, and by the time we finished the study everyone that was interested had moved on to other things.

Question: Do you have an estimate of how the presence of plants would enhance degradation rates compared to bulk soil?

Reply: That's the embarrassing part. We didn't have an unplanted control. That's probably the first greenhouse experiment that I've ever done where I didn't have an unplanted control and the reason we didn't is because we were focusing on this idea that the cycling treatment would be very effective relative to the controls and the controls we thought would be most appropriately continuously flooded and continuously aerobic. You know…. in fact that wasn't even a phytoremediation experiment. The idea behind the plants was that it could very quickly cycle the soil from flooded to aerobic. So the presence of plants was kind of incidental to our study and we thought that the cycling was far and away the most important treatment, or the most important factor, but in actual fact, I think that the presence of the plants under any growth condition was the crucial factor.

Question: Right. Plus plants may help you get that cycle you know.

Reply: Yes. Plants are very effective in helping us with the cycling because we can very quickly convert the soil from flooded to very well drained within a matter of a day or so because the plants are using water like crazy.

Question: It seems like the big problem with DDT, DDE and the rest is how the mobilizing soil systems seem to be partitioned out to various materials. Do you have guesses how that might be working here? You indicated some potential modes with the umates(?), the phenolates(?), the lignin surfaces but it seems like one of the big problems is getting the substrate to the microbial films, whatever is breaking them down and how that works in nature is still anybody's guess.

Reply: Yeah. They're very hydrophobic. They have very low water solubility.

Question: I'm just curious, with the microbic insorcia(?) are able break these down there's electron addition and there's oxidated steps, would you make any guesses as to what you think might be operative here where your getting, you seem to be dropping the whole group in terms of all the concentrations?

Reply: Yeah. I just don't have a clear idea of mechanism. No. I was surprised by this step.

Viridian Resources (Drs. Li and Chaney)

Question: Dr. Chaney, you showed one case where, with the addition of high pH materials, you were able to shift the partition co-efficients to the left with the light in the soils and the other case you actually showed that you were able to shift the sulfate reduction co-efficients to the right. Have you run into situations... obviously, it's clever when it can work, but have you run into problems where you utilize the high pH environment and it later becomes the wetland for remobilization of the materials that are otherwise fixed?

Reply: Um. Let me say that in two ways. If we had a combined contamination of say, molybdenum and something that is insoluble at a high pH like copper or zinc or so on, then we

would have to be very careful about molybdenum accumulation and forge materials. That's not a problem in this case. The issue of it becoming flooded or seasonal wetland as these wetlands are, if I make it calcareous(?) so that any of the other metals are not important, that also helps convert and keep the mercury as sulfide. Those of you who are not familiar with the Oak Ridge, Tennessee situation with mercury where they lost over 100 tons of mercury from their operations into the local rivers – something that is much more remarkable than the case here that it just orders of magnitude in comparison. In that case, they found that, except in the surface soil where it was aerobic, almost every bit of the mercury was mercury sulfide. The Risk Assessment for the terrestrial part of the system had to do with bioavailability of ingested soil mercury as opposed to aquatic bioaccumulation that Rich Meagher showed us about. Certainly we all recognize the importance of avoiding aquatic biomagnification, but we don't have the same thing on terrestrial systems, and promoting sulfide precipitation of mercury in all of the seasonal wetlands seems to me a perfectly appropriate solution that has been accepted elsewhere, and I think that if the Lab and the citizens look at the information and do preliminary tests, certainly Dr. Li and I believe in demonstration tests on the particular materials at hand after we work out a recipe tailor made mixture that is economically appropriate out here on Long Island.

Question: Even with what looks to be a high quantity of organics that you have in your mixture altogether, you don't think actually that you'll establish carbon dioxide reducing conditions, essentially mentholating conditions, that can move mercury out of those situations like this.

Reply: In this aerobic system, the part of the year that it is aerobic, remember that there is a lot of organic matter there in the first place so we're not going to be shifting that. We're as interested in adding some clay, some bentonite to the system as we are in adding anything to do with organic matter. We just think that a leaf compost or any other compost-type material could be mixed with a clay and give a cover so we don't have direct ingestion of soil exposure so that just minimizes that last route of exposure. Certainly we don't have any evidence it's going to mobilize it from the liturgy(?).

Panel Discussion on Phytoremediation

Question (Jim Lister, NYSDEC): (Looking at specific contaminants) The individuals from Viridian seem to me, did evaluate the contaminants of the site, the metals – especially copper, silver and mercury – with respect to their ideas as to whether or not they could be dealt with. I was wondering if any of the other individuals had any other experiences with each one of those contaminants? I remember a talk on mercury but copper and silver both seem to be devoid from any evaluation.

Reply: In many cases, I think each of us would have to do some kind of preliminary identification of species, some kind of treatability study to try to decide which strategy to use. For PCBs, for example, no one presented anything. I don't think that there have been many plants identified which degrade PCBs, but I don't doubt that we could identify such plants. That

would be the first thing we would do. Survey the site, ask which plants are there, see if any of them have degrading capabilities and move on from there.

Question: The real drivers from a regulatory standpoint are the heavy metals.

Reply: Sure. For the mercury, I really don't disagree with Rufus' comments that the biggest concern is the aquatic mercury, and I don't think we know enough to know how many trophic levels there are and how much biomagnification is in that particular aquatic ecosystem, but I'll guarantee you there is biomagnification in that mercury in the aquatic system is a problem. I don't think anyone should doubt that. We still have to do something about mercury, but it's really hard to know about these other metals and there are regulatory standards.

Question: But, what I'm really looking for is any experiences using phytoremediation as a remedial technique to get these contaminants down to numbers that we're looking at.

Reply: Yeah. I might be able to address that. I think that what we're dealing with here is multiple sites, multiple contaminants. We have both organic contaminants, metals. We don't know what species the metal contaminants… We know we have a variety of geochemical conditions and know that it may vary throughout the year and the geochemistry is going to have a big effect on the bioavailability of these particular contaminants, and whether the processes involved in the geochemistry such as reductive dechlorination(?) are actually, in fact, affecting some of the other organic contaminants. I agree with the statements earlier that we need to look at the sites. We need to look at your data that you've collected and we have to decide is there a real risk here, first of all, and zero in on which contaminants we feel are most at risk. And then, from there, you devise your strategies, and those strategies might not be the same for each and every site. They may be different for all five sites. They're each unique. So yes, we've covered a range of things and no one has a "quick fix". Like I said, under certain conditions, under reducing conditions, you're going to make things less available; you're going to make other contaminants more available. So how do you deal with that issue? You're definitely going to have geochemical conditions that change throughout the course of the year. As you dry up your wetland, you're going to reduce oxygen. It's going to reduce to probably aerobic or oxic conditions. So these are the things you'll have to deal with.

Reply: I think when you look at the redox of a wetland in terms of iron, manganese and so on, I don't see much implications for the bioavailability of these metals, of phyto-availability. We also believe that the mercury technology, particularly in plants, that could be in the emergent wetland or the seasonally flooded wetland would be a complementary solution that would be wise to try in any case. I've said in the public before that I believe that for lightly contaminated sites like this, removing the risk by volatilization, putting it in the global mercury pool, is the wise answer. For a site that's got tons of mercury, of course that's not the right answer. And the point that he made…the channel…and maybe only the channel needs to have this serious concern about mercury, not the rest of the wetland. I think that the risk assessment evaluation would need to be completed to figure that out.

Question (Kevin McAllister, Peconic Baykeeper): You all have tried to exemplify your successes throughout the country in dealing with cleanup projects focusing mainly on again

metals and VOCs. Do you have experience with the radionuclides in some of these other projects and are phytoremediation applications applicable here dealing with that significant problem which is really a fundamental problem why we're here today. Thank you.

Reply: All the easiest stuff has been done. And no this isn't … if there was an answer for that we wouldn't be here today. There are some challenges here. There hasn't been a lot of work done with this suite of contaminants, mainly because this is the first time anyone has asked to do that. There are a very few sites that have these types of conditions so I'm not aware of any work that has been done with that suite of contaminants – copper, mercury, and silver together in that situation. On the other hand, there is a lot of data out there on copper uptake in plants. Have we done any work on cleaning these? We've done work on cleaning copper-contaminated soils with plants, but it was with lead. It was with lead and copper. We focused on lead. We had copper uptake at the same. I would say there isn't any data out there that I'm aware of that shows those three contaminants together. That's why none of us presented that data, because it's a new problem for us. It's something that has to be designed for, as with any site that we deal with. We go to a site and we see what the problems are and we design a solution based upon our experience and knowledge. Now our experience, I'll have to admit, here is rather limited with those elements.

Reply: (Dr. Meagher) I think, maybe I'm backing up a little too far but I would like to make a comment that's particularly directed at the public who's trying to figure what's going on and how we can be so ignorant about some of these problems. If we were working on a medical problem we'd come in here with forty years of solid literature, NIH funded, NSF funded behind us to make a plan. There has only really been funding to the phytoremediation community since about 1996 at any significant level, and it is still .1% of what NIH spends on medical research. So we don't have a huge base of literature behind us that we can go and look up about 20 different ideas and try and fit them together and say, that ought of work. We just don't have that. So most of us only know what we've done and what each other has done and we don't have this big literature base to go to design all of our experiments and that is really one of the things that makes us in an awkward position to say absolutely that this is the right trick. Studies and modeling become very important to us at this site.

Barry Lawson: Anyone in the panel disagrees with that?

Reply: I can't disagree with that but I think that we have decades of experience on immobilization of contaminants. For instance, in the wetlands, cesium, although the work that Fuhrmann and all have done with pigweed amaranthus, taking up cesium is very creative science. The first people to have significant funding to work on cesium phyto extraction. On the other hand, we can alleviate the risk of that with a bentonite clay, putting it between the layers and it's out of the exchangeable pool. If I fertilize with potassium, I can inhibit uptake so it's not taken up; just making sure that there's a reasonable potassium fertility. If it were a high level of cesium, we would have to talk about excavation and either disposal or phytoextraction. But in a case where it is not a limiting risk by itself, as long as we are not going to make it worse with our remediation, then it's still not a risk.

Question: This is kind of going to be softball for the panel. I consider myself to be someone who advocates very strongly on phyto and maybe a little bit of a hardball for our potential customer DOE. I have heard just about everybody from this morning to now discuss the absolute mandatory requirement for some form of a field demonstration. I believe the people on the panel would nod favorably at that. I'm not certain that our customer who called us here today to have this presentation are necessarily in that same mind set where there's the time frame or the monetary commitment to do a funding of some form of a pilot. If all of the people on the panel would agree that a pilot is necessary, we could probably make this day a lot faster if DOE tells us that there is neither any dollars nor any time available to us in this process to do it. So I would like to ask that question back to whoever can answer that. I apologize for not lending a question to the panel.

Barry Lawson: Is there anyone brave enough to answer that question?

Reply: I had a sense, unfortunately, and I tend to be pretty much a person who looks at a half filled glass and sees half filled as opposed to half empty. But I have a growing pessimism as the day moves forward that the possibility exists that there either is the time or perhaps the stamina or the dollars to commit to doing a necessary treatability that might be needed for this project.

Question (Frank Crescenzo, Acting Manager of the Brookhaven Group): I think he's asking that question because we had a little discussion before we came in. I'll turn a question back to you. Why should the Department of Energy invest in R&D for this sort of technology when there are technologies that exist on the shelf? Keep in mind that I have to go back to my Program in Chicago and Headquarters and to our regulatory partners and say, "Hey, we have to do an R&D before we even know if this thing will work". So…there is money if the risk is reasonable, ok, but there is not money in this program to simply just do R&D just to prove that plants can uptake certain contaminants. It has to make sense for this project either in terms of its invasiveness to the environment, or its cost savings, or in its effectiveness. So I would turn the question back to you. What are those parameters and how will you sell "it" to the Department of Energy?

Reply: I would like to make just one short comment. I think everybody here could add something to this. First, if we're going to work on the mercury technology which I think nothing is going to match, what we've done with methyl mercury, nothing. Right? But if we were going to use that for this site, we'd have to engineer some particular species that are suitable to this site, preferably something from this site – some particular species of cottonwood or some particular willow that was growing along this river. We'd have to do this. It would take time. If we were going to look at PCBs or we're looking at the particular degradation of DDT at this site, we want to look at species that were suited to this site and that takes time. Then we'd have to test it on the soils from the site. And I really wouldn't want to do it any other way.

Reply: I was just going to add that you do have a number of sites, that you do have to consider that cost is a factor here. There is some R&D and time that is a factor as well. You have a number of options that are feasible on your agenda already, and one of them is to, and it may not be palatable to everybody, but that is the removal piece and I would suggest that one is the basis

for comparison, so you have to take into consideration that there are some dollars for the R&D. I'm being totally honest here.

Reply: That was $5.2 million and I'm sure that the remedy that we talked about would be far less direct cost because we're not removing and restoring the entire wetland ecosytem. I think that the citizens were on good ground to say, "Do you really need to do that"? Isn't there a better answer there? Because when you tear it up, you really can't make it as good as it was when it started, unless it's already been destroyed as in some other locations we're all familiar with. I think the savings potential for DOE and the public is more than enough to attempt a limited area trial to accumulate the information from corresponding studies. I've got a study, somewhat similar to this, at the Aberdeen Proving Grounds with a metal carrier, and EPA supervised Superfund tests. I think we are all familiar with alternatives that would save money and that's the main reason this could be a useful meeting.

Question (Marsden Chen): Could you pursue this spot a little bit? I think it's very important and as a regulator I'd like to make a comment if I could. I'm from the state of New York also. I'm a layman in phytoremediation. I don't even know how to spell the word. So…I need people to draw pictures for me. We had one of these meetings many months ago in our regional office, and the conclusion there was that maybe it could work, maybe it could not work. But what I heard this morning is that for certain parts of the river, we would have to divert the river to get into the contaminated areas. Now aside from water lilies, I don't know what other type of plants you could put there now for the uptake of the contamination. I also heard that, well, we want to bind the contamination, and I don't know how that's going to be done. But I also heard Risk Assessment also. And Risk Based Criteria is a term that we use. Now, in the State of New York we have the regulations and we have those to be considered. And those take priority over Risk Based Criteria. So the question is…The State has adamantly refused to accept Risk Based Criteria. If I go back to Albany tomorrow it will change, but right now that's the stand. We have to observe the regulations that are to be considered. We have mercury, lead, and whatever else is there where we have cleanup goals. And those are the things that you're driving for, not to leave them in the sediment. So with all of that said, let's go back again and I heard that if we're going to do treatability studies, then we've got to do it for PCBs, lead, one at a time. How much time are we talking about? Five years. Ten years. You know, the ROD has been signed, oh, no? The proposals have been made. I'm sorry. I misspoke. Thank you very much. The proposal has been made for the cleanup criteria to be met so how much more time are we supposed to endure going through this until we get the ROD signed and get to a remedy? Are we talking ten years from now?

Reply/Comment (Bill Smith): Can I make a comment about that as a member of the community? To address that, my comment is that it took forty-plus years for this nightmare, this environmental nightmare, to occur and if the regulators were, in fact, as concerned about it as they would like us to believe, they would have been watching the whole situation and not allowing the Sewage Treatment Plant to discharge all these contaminants into the river and to create the situation in the first place. So, I think again, that it is a moot argument. I think as far as the timetable, if it takes another year, another two years, it doesn't matter at this point. The responsible thing to do here is to clean it up. Clean it up effectively. To clean it up with as little

as possible disturbance to the environment. This is the way to do it. The argument that this gentleman from Albany made, as far as I'm concerned, is ridiculous. If they had been watching this whole situation for forty years, we wouldn't be here today.

Reply: I would just like to propose something and see whether the panel wouldn't agree, just to give somebody a feeling for time scale. If we were doing this, and I think maybe if other groups were doing this, the treatability studies that you're talking about aren't done sequentially. They're all done at one time for the different contaminants. We talking about six to nine months from this moment, if someone said to do it now and we'll pay for some of this. And then you'd probably want to do some field-testing and that might be twelve to eighteen months. So I think two years is a reasonable thing to be absolutely sure at the end that what you do on the large scale is going to work. Does that sound right?

Reply: Just to make that clear, the bench-scale testing in the lab and then going to the field.

Reply: (Dr. Li) The approach we propose, we think, would be a shorter time needed to pull this technology to work. (The remainder of his reply is very difficult to understand).

Question (Dale Pflug, TechCon): I'd like to address the panel in this way. The presumption in inviting you all here was to see if phyto or some other alternative to removal was a viable approach. And so the presumption is that the regulators have got to make a decision in terms of whether something can be implemented. I would ask you, and you certainly can't do it instantaneously here, but as a group, if you would have some discussions as to what you can do or what the site could do to qualify opportunities, either whole or in part, to implement phyto as a remedy, how long that would take and the approximate cost would be very helpful to the deliberations here.

Reply: (Dr. Li) I will just answer part of your question. It's a hard question to answer at this point. There's not much information available at this point. We feel that with minimum cost (again – he's very difficult to understand).

Rely: I think the cost of every group... nobody asked for proposals with a figure attached from each of the groups. It is probably premature to do that. Some time, DOE has to figure out whether it would be cheaper from a company offering the service than their own calculations, which are based on assumptions that may not be close to what the companies would believe, actually handles the risk reduction that is required. So I think everybody would rather say that the estimate of $2 million more than removal, maybe that wasn't even close to a reasonable statement of difference of cost between phyto as anyone has talked about it and removal.

Question (Sven Hoeger): I have a very practical question for all of you. I believe in phytoremediation. I like very much the approach of using plants to remove and not disturb the soil. I have a very big difficulty understanding how you would practically actually approach such a project at this particular site. I remember seeing site photos; Site A seemed to be a very dark site, there was little light in there so I don't see that we could even grow plants on that site because plants need energy from the sun and that's the only way that they can extract anything, especially if it's difficult to extract. So they need a lot

of energy. The other open sites; they're still pretty muddy. We were told that you sink in at least six inches into mud. It all involves a little bit more than just sprinkling a few seeds or planting a few plants and that's the practical question I'm going to ask you because I feel it has a big impact, importance in terms of deciding later on what's going to happen.

Reply: We just finished a site yesterday after I left town working with URS and another company in Georgia, and basically, what we did there was to identify those plants that had no activity towards the target compounds and all of those, or most of those, were removed from the site and some of the plants that had no activity to the entire compounds from around this perimeter from around this site for 20 to 30 feet were also removed for this exact reason that you're talking about. Just trying to let more light into the site so that we can put in the plants that have the activities that we're going to work with. So that's an intimate part about the decision making process and we're still kind of young and naïve, I guess, about just how much light we need and we may wish we had taken out more plants, but right now we're trying to err on the side of being a little conservative about removing anything that's there in the first place right now. We are definitely taking that into account – trying to let more light into a site. Get out plants that don't have activity.

Question (George Proios): I would like to follow up on site-specific characteristics that haven't really been addressed. I want to go back to the pH issue and just point out two interesting factors on the river: 1) it is the most acidic river on the island. It has a lot of tannic acid, very low pH. So I'm not quite sure how you could have uptake without doing some manipulation of pH. So I wanted to see whether or not you agree that you can operate under those circumstances. It's also extremely low in nitrogen. So besides not having sunlight, you also don't have any nitrogen to feed the system and that's why we have several insectivorous plants that are on the State's protected species list. So without adding anything to change pH, without adding nitrogen, without sunlight, again, these are all extreme limiting factors that you still think, I know you want a pilot project, but are these also additional burdens in order to make this type of technology work here.

Reply: Yeah. Those are burdens and they are difficulties and they will have to be addressed. The question is that if you plan to excavate the soil, don't those also have to be addressed? My point is that there is always a trade off. If you want to remove the contamination, there's something you're going to have to give up. You can't leave the contamination and have everything exist perfectly and so then it's a matter of what do we trade off to get the maximum benefit? Do we have to make some adjustments in the river flow? Do we have to remove some of the existing vegetation in order to accomplish the greater good of removing the contaminants? And if that's what we decide is the greater good. And so that's the point. We have to understand what are our goals here and what is the most important thing? Is it the most important thing removing the contaminants and preserving the ecosystem that seems to be the goal. Well then, how do we most effectively accomplish that? Certainly, there's going to have to be some adjustments made. You know you can't grow plants in the… it's going to be very difficult to get the plants to root into sediment that is three feet below the surface of the water. That's an issue as well. So, there are some things that are going to have to be addressed if we want to remove the contaminants. If you want to leave the contaminants in place then you don't have to do very much.

Reply: I would agree with Mike. You basically have to approach it with all your options. You have to treat it as a feasibility study and look at all those options and weigh all your options. Do you want to disturb the site? Do you not want to disturb the site? Do you want the contaminants to go away? These are the things you have to consider. It has to be a feasibility approach. How else can you compare the damage that you may cause by going in and excavating and knowing that the contaminants are gone but then you're into a restoration program? I agree totally with Mike. You have to weigh them all.

Reply: I think there's always the question of removal or alleviation of risk. There are lots of things that we can remove – the environmental risk, the human risk – without having to remove all of the contaminants. For instance, right now there is a nationwide argument going on about arsenic in drinking water and the reference to that with soils and the number that EPA has talked about would require us to replace 90% of the earth's surface. Somehow there's a disconnect there. We have to get common sense into these decisions, and if we can alleviate the risk with in-situ remediation or a combination of mercury volatilization and fertilizer enough to have active vegetation doing the biodegradation. I think that's a good public answer.

Reply: I think the other thing to do is to try and see what can work in the positive for you. We have sort of two extremes about how to handle the metals. We could try to bind them up by increasing the pH, but the acidic pH can actually work for us if we select the right species. The acidic pH will make more things available for trying to extract the mercury out of the system. It will move faster under acidic pH conditions. Nitrogen we can put into the right species. There are native species in this area that fix nitrogen. There's really ways to handle these problems. We just have to decide how to do it.

Question/Comment (Adrienne Esposito): Although the regulators are using the heavy metals as the driving factor for remediation plans, there are large sections of the community that are also looking for the radionuclides to being cleaned up as well. In the past, it hasn't been too much of an issue because the radionuclide contamination, the highest levels have been co-located with the highest levels of heavy metal contamination. So in the remediation plans, we just want it noted that we're looking for technology that would be able to accomplish both. The cleanup of heavy metals as well as the cleanup of radionuclides. We haven't heard much today, and I know that this is a new science, but we are looking for both of those accomplishments.

Reply: We have worked with radionuclides as well, but if the radionuclides you're referring to are cesium, cesium-137, that presents an additional challenge. There are soils that cesium is taking up, you know, plants take up cesium from some soils. That is a tough issue. To say that we can remove all the cesium would be a difficult thing to do. I can't promise you that plants can do that. We've seen data where plants take up fairly good rates of cesium, but it's not going to occur everywhere.

Reply: The plants like amaranthus, which has been illustrated at Brookhaven, it requires a fully aerobic soil depth for phytoextraction and the wetland is not really a great place to try and grow amaranthus. If removal and treatment is the choice, then one could do some metals and one

could do radionuclides or this or that in sequence. There is no way today to do them all at the same time, even if you removed it and managed it on a controlled site.

Question: In general, a great number of phenomena have been addressed and different mechanisms for capturing metals and other materials, but implied earlier a few moments ago by Dr. Chaney, there are already geochemical and bio-geochemical mechanisms operative out in the wetland like this that there are in the rest of the planet. What we haven't heard is how the bio-geochemical regulators, the sources and the sinks, the gradients, the partition co-efficients in that ecological system now, or those ecological communities, are operative in holding materials and protecting human health – how they might be enhanced, strengthened, conserved and, maybe in some cases, replaced by the kind of exquisite technologies that have been described here and it seems like for the sake of the Peconic River estuary and the headwaters, this would be a great step forward because we would have done what SECA and everyone requires. What's the no-build alternative? What's nature doing for us now?

Reply: It should be part of the record that's available at the website, but none of us could find it.

Reply: Actually, you might just add that there is a number of…you touched on it…that the geochemical conditions are quite diverse and they do vary from different times of the year. The important thing is that you probably had a number of constituents that have been coming out of the treatment system for some time, but you're only seeing small impacted areas. So, the ecosystem that is there has probably been dealing with this and there is probably some evidence there, some natural stabilization going on, natural stabilization, there's some natural uptake occurring and in these areas where you have these conditions some of the material has fallen out. These are rich concentrations. I think you touched an important point that you do have to look at the geochemistry as part of your feasibility.

Question: Just a practical consideration, it seems like a lot of your collective experience involves sites with relatively large quantities of relatively highly contaminated material, and I wonder if you're comfortable enough with the estimates of the volume of contaminated sediments and the level of contamination and maybe with the wetland sediment issue, it's less volume but it's more surface area or acreage, but are you comfortable that the economy of scale might apply to this business, this technology, this industry, that's not a factor that would make phyto either better or worse for the Peconic sediments because I heard earlier about estimates of areas of contamination changing with additional data coming in. I was just wondering how comfortable you all are with either if its volume or surface area that you have to deal with that keeps you in the ballgame economically.

Reply: Actually, I'm just going to elaborate on that last statement. It sort of plays right into your question and that's the concept. Everyone has heard of natural attenuation, well there's the concept of intrinsive phytoremediation, in other words, you have a natural ecosystem that contains plants and these hybrid systems can deal with contaminants and I suspect, and leaving off the last comment, that there is a fair amount of intrinsic phytoremediation that is actually occurring at your site. And again, I'll go back to you've got some small spatially distributed

areas where it is just a little elevated compared to the rest, so I think that the mechanisms are actually in place here and we just have to enhance the conditions for these other areas. And whether we do that as far as a treatment wetland or whether we go in and try ex-situ techniques, they all have to be on the table to be evaluated.

Reply: To address your question about the economy of scale, you know, when I went out and walked the site, there are areas there that the economy of scale will work against you. That river is not designed, you know, is not going to give you the economy of scale savings that you want in some places. On the other hand, my understanding is the reason we are here discussing phytoremediation as an option isn't strictly economical. That there were other concerns is why we want to do phytoremediation here as opposed to excavating and removing the soil. So, the cost savings, you know, I don't know without going out and doing a thorough evaluation as far as the cost. There are some areas where, you know, you have large areas – it's easy to work with. Others areas are going to be very small and will cost more than you would anticipate, for phytoremediation that is. The economy of scale – it's difficult to say, but I'd say that's not the overriding concern. I could be wrong.